THE ROCKY FLATS CLEANUP AGREEMENT (RFCA)

RADIONUCLIDE SOIL ACTION LEVEL (RSAL)

WORKING GROUP (RWG)

TASK 2 REPORT

COMPUTER MODEL SELECTION

U.S. Department of Energy
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EXECUTIVE SUMMARY

The Department of Energy (DOE), the Environmental Protection Agency (EPA) Region VIII, and the Colorado Department of Health and Environment (CDPHE) entered into the Rocky Flats Cleanup Agreement (RFCA) July 19, 1996 In October of 1996, DOE, EPA and CDPHE established two action levels for radionuclide contamination in surface soils (Radionuclide Soil Action Levels (RSALs)) According to the "Action Levels for Radionuclides in Soils for the Rocky Flats, final 10/31/1996, Tier I action levels are numeric levels that, when exceeded, trigger an evaluation, remedial action and/or management action, given the presence of institutional controls Tier II action levels are numeric levels that, when met, do not require remedial action and/or institutional controls " The Radionuclide Soil Action Level (RSAL) Working Group (RWG) understood that setting action levels for radionuclides was a complex process and changes could occur in the future that might impact the original RSALs The RWG agreed to evaluate new information as it became available that might impact the 1996 RSALs The current RWG mission of evaluating new information consists of five actions or "Tasks" Task 1, Conduct a regulatory analysis, Task 2, Computer Model Evaluation, Task 3, Parameter Evaluation, Task 4, New Scientific Information, and Task 5, Cleanup Levels at Other Sites

The determination of appropriate dose limits that are protective of the public and environment is identified in Task 1, Regulatory Analysis

Task 2, Computer Model Evaluation (Selection) of the RSAL report describes the process that will be used to evaluate and select a computer model to calculate radiation dose and recommend soil action levels Several computer models were candidates to calculate the RSALs These models include 1) RESRAD 6 0, 2) DandD 2 0, 3) Risk Assessment Corporation (RAC) Code, and 4) the MEPAS/GENII/FRAMES/SUM3 package of computer codes These computer models were selected for consideration because they can assess radiation dose from soils in a probabilistic manner and they can trace the movement of radionuclides in the environment over the 1,000-year assessment period Task 2 of the RSAL report outlines the seven model selection criteria that were used to select the best model for determining RSALs at Rocky Flats It also briefly describes the capabilities of each of the computer models chosen for assessment and evaluates each of the models with respect to the selection criteria.

The conclusion reached is that RESRAD 6 0 and MEPAS/GENII/FRAMES/SUM3 are the computer codes that satisfy all of the selection criteria and that RESRAD 6 0 was the better choice based on previous site use and familiarity with the code

Finally, it should be noted that the RFCA parties have agreed to also calculate RSALs on the basis of risk in addition to the calculations based on dose For the various scenarios, potential RSALs will be calculated to risk levels of 10-4, 10-5 and 10-6 The risk levels will be calculated using the standard slope factor method that has been employed by EPA for over 10 years The method for performing this type of calculation is provided in EPA's "Risk Assessment Guidance for Superfund (RAGS)" Volume I (1989) The

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National Research Council first recommended this method of risk calculation in 1983 The EPA guidance document "Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination," OSWER No 9200 4-18, August 22, 1997, expresses an agency preference for using the RAGS approach for assessing cancer risks The Task 3 report will include a detailed discussion on the RAGS process for calculating values as well as a list of the equations and rationale for all the parameters chosen for the calculations

1. Introduction

The lack of a single comprehensive set of regulatory action levels for radiation, together with the confusion as to the status of other Federal Agency regulations and guidance for establishing action levels, has caused uncertainty as to the action level deemed protective of the public and environment The determination of appropriate dose limits that are protective of the public and environment is identified in Task 1, Regulatory Analysis Once the appropriate dose limit is defined the concentration (typically expressed in pCi/g in soil) which will result in that dose limit must be determined so there is a measurable means of identifying what soil needs to be removed to complete the cleanup A Radionuclide Soil Action Levels (RSALs) is a radionuclide concentration that, given the appropriate land use scenarios and site parameters, will reasonably ensure that individual dose limits will be achieved The RSAL is determined by performing a pathway analysis that sums the exposures from different pathways (air, ingestion of contaminated foodstuffs, water, etc) Using a computer model that calculates and sums all the doses from the primary pathways of exposure to the radionuclide does this

Task 2 of the RSAL report describes the process that will be used to evaluate and select a computer model to calculate radiation dose and recommend soil action levels

Analyzing the release and migration of radionuclides through the natural environment, at a specific site, requires the analyst to interpret the nature and features of the site so that the site can be represented by mathematical equations (i e , mathematical models) This simplified representation of the site, including the associated mathematical model, is commonly referred to as the site conceptual model Mathematical models are a quantitative representation of the site conceptual model Computer models are used to calculate RSALs due to the complexity of calculating a radiation dose to numerous individuals for a range of future land uses Computer modeling is an interactive series of questions and decisions

Uncertainty is inherent in all dose assessment calculations and must be considered in decision making In general, there are three primary sources of uncertainty in a dose assessment, uncertainty in the models, uncertainty in the land use scenarios, and uncertainty in the parameters Computer models are simplifications of reality, and in general, several alternative models may by consistent with the available data Uncertainty in scenarios is the result of our lack of knowledge about the future of the site Parameter uncertainty results from the incomplete knowledge of the model coefficients In the past, dose assessments have primarily included the use of deterministic analyses The deterministic approach has the advantage of being relatively simple to implement and easy to communicate to stakeholders However, it has a significant drawback in not allowing consideration of the effects of unusual combinations of input parameters and not providing information on uncertainty in the results Furthermore, a deterministic analysis usually relied on overly conservative estimates in order to have a high assurance of not exceeding any dose limit For a deterministic dose, an average or mean of a parameter is used in a simple mathematical form controlled by multiple assumptions to determine a single dose number

Probabilistic analysis is now regularly applied to environmental modeling The probabilistic approach is to choose a distribution of values for the most sensitive parameters from the model Probabilistic analyses frequently use the Monte Carlo method Input parameters for the models are selected randomly from probability distribution functions These techniques consist of assigning a probability distribution to each parameter that is treated as uncertain Parameters chosen in a probabilistic manner will produce an output set of radiation dose distributions over time for each radionuclide in each exposure scenario The use of a probabilistic approach was one brought to the attention of the RWG by the Risk Assessment Corporation in their review of the RSALs in 1999 For a probabilistic dose, a series of parameters that have uncertain values with non-uniform properties are used to produce a probable distribution of dose values Calculation of radiation dose from soils at Rocky Flats will involve multiple radionuclides (plutonium, americium, and uranium), multiple exposure pathways (ingestion, inhalation and external irradiation), and multiple exposure scenarios over a 1,000-year period Therefore it is important that the model selected be able to calculate a probabilistic dose

Several computer models were candidates to calculate the RSALs These models include 1) RESRAD 6 0, 2) DandD 2 0, 3) Risk Assessment Corporation (RAC) Code, and 4) the MEPAS/GENII/FRAMES/SUM3 package of computer codes These computer models were selected for consideration because they can assess radiation dose from soils in a probabilistic manner and they can predict the movement of radionuclides in the environment over the 1,000-year assessment period One other model, MMSOILS, developed by the US EPA's Office of Research and Development, was considered early on in the process, but was eliminated from further consideration because it was not thought possible to apply it to radionuclides

Task 2 of the RSAL report outlines the model selection criteria that were used to select a model for determining RSALs at Rocky Flats It also briefly describes the capabilities of each of the computer models chosen for assessment and evaluates each of the models with respect to the selection criteria The results and conclusions of the evaluation are included at the end of the document

2. Model Descriptions

2.1. RESRAD 6.0

RESRAD is a computer code developed by Argonne National Laboratory for the U S Department of Energy to calculate site-specific residual radioactive material guidelines using radiation dose and radiation risk These residual radioactive material

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guidelines can be developed on a deterministic or probabilistic basis Residual radioactive material guidelines are equivalent to an RSAL at RFETS

RESRAD uses a pathway analysis method in which the relation between radionuclide concentrations in soil and the dose to a member of a critical population group is expressed as a pathway sum, which is the sum of products of "pathway factors " Pathway factors correspond to pathway segments connecting compartments in the environment between which radionuclides can be transported or radiation emitted The nine environmental pathway segments assessed by RESRAD are direct exposure, inhalation of particulates and radon, and ingestion of plant foods, meat, milk, aquatic foods, water and soil

2.2. DandD 2.0

DandD (Decontamination and Decommissioning) is a computer code developed by the Nuclear Regulatory Commission to support decommissioning under their License Termination Rule Screening level cleanup concentrations are calculated by DandD for surface soils and building surfaces using probabilistic analysis The DandD computer code software was developed using the environmental pathways and exposure scenarios documented in Volumes 1 and 3 of NUREG/CR-5512, "Residual Radioactive Material From Decommissioning "

DandD assesses a residential exposure scenario for soils and a building occupancy scenario for building surfaces The building occupancy scenario relates volume and surface contamination levels in existing buildings (presumably released following decommissioning for unrestricted commercial or light industrial use) to estimates of the total effective dose equivalent (TEDE) received during a year of exposure with the conditions defined in the scenario The more complex and generalized residential scenario is meant to address sites with contamination in soils and groundwater Input parameter distributions for each scenario and exposure pathway were developed consistent with conducting screening dose assessments, increasing the likelihood of overestimating rather than underestimating potential dose

2.3. RAC Code

The Risk Assessment Corporation (RAC) wanted to assess exposure scenarios and exposure pathways in a probabilistic manner RAC also wanted to calculate the amount of radioactive material in the air differently than previous RESRAD models Using RESRAD 5 82 as the baseline, RAC developed probabilistic computer codes and air modeling computer codes to generate its own computer model RAC's modification of RERAD 5 82 provided an air pathway calculation that differs from that of the original code This modification constitutes a departure from RESRAD's formulation, in a manner that has not been fully documented

In February 2001, a report was prepared titled "RESRAD AIR CALCULATIONS" by Radian International that compared the various air pathway calculations found in different versions of RESRAD and the RAC Code The study was designed to identify the differences in air pathway calculations and the resulting affect on the generation of a RSAL The conclusion of the report was that the different implementations of RESRAD produce different RSALs, partly due to differences in the air pathway calculations, but more importantly, differences due to other factors and assumptions The report states that "the new RESRAD formulation is based on more supportable assumptions that were derived using a well accepted dispersion formula RAC Code's implementation produces air pathway calculation's **in the range** (emphasis mine) of new RESRAD but the resulting RSALs are highly sensitive to collateral assumptions, including the location of the receptor, the size of the contaminated area, and most importantly fire effects " In can then be concluded that the RAC Code and the new RESRAD are similar with respect to the air pathway calculations and that RESRAD 5 82 was left unchanged therefore should not be the deciding criteria

The RAC code can assess multiple exposure scenarios and exposure pathways in a probabilistic manner

2.4. MEPAS/GENII/FRAMES/SUM3

The MEPAS/GENII/FRAMES/SUM3 set of computer codes works as a unit to calculate radiation dose to individuals associated with multiple exposure scenarios FRAMES is the shell in which all of the other computer codes run MEPAS and GENII contain the source term definition component, the fate & transport component and the radiation dosimetry component of the set of computer models SUM3 is the package that allows the use of probabilistic analysis within the set of computer codes These four computer codes are further discussed in the sections below

2.4.1. MEPAS

The MEPAS (Multimedia Environmental Pollutant Assessment System) computer code assesses the impact to individuals from radionuclides and chemicals in the environment MEPAS integrates environmental transport and exposure pathways to determine their potential impact on the surrounding environment, individuals, and populations MEPAS is a deterministic computer code that can assess multiple exposure pathways and exposure scenarios

MEPAS provides a user-friendly interface for setting up cases and analyzing results This interface provides on-line help, units conversions, pictorial depiction of the Conceptual Site Model, ability to reference all data, ability to edit most default parameters and graphical views of input and output data. MEPAS is applicable to a wide range of multimedia transport and consequence analysis

2.4.2. GENII

The GENII computer code was developed at Pacific Northwest National Laboratory (PNNL) to integrate radionuclide dosimetry models with environmental pathway analysis models The resulting second generation of environmental dosimetry computer codes is compiled in the Hanford Environmental Dosimetry System (Generation II or GENII) Although the codes were developed for use at Hanford, they were designed with the flexibility to accommodate input parameters for a wide variety of generic sites

The GENII system includes the capabilities for calculating radiation doses following chronic and acute releases, with options for annual dose, committed dose, and accumulated dose Radionuclide transport via air, water, or biological activity may be considered GENII is a deterministic computer code that can assess multiple exposure pathways and exposure scenarios

2.4.3. FRAMES

FRAMES (Framework for Risk Analysis in Multimedia Environmental Systems) is a software platform used to link different computer codes required to perform an appropriate assessment FRAMES is an open-architecture, object-oriented system that provides an environmental database This software platform aids the user in constructing exposure scenarios and exposure pathways applicable to site-specific situations Furthermore, the software allows the user to choose the most appropriate codes to solve simulation requirements and presents graphical packages for analyzing results

FRAMES currently contain sockets for a collection of computer codes that simulate elements of a source, fate & transport, exposure, and risk-assessment system FRAMES provide data file specifications that describe how all site information is stored within the framework and passed between modules These data file specifications are not associated with the model-specific information, only with the transfer of information between modules or other frameworks The environmental transport and radiation dose computer codes currently available within the FRAMES software platform are MEPAS and GENII SUM3 is an additional computer code available in the FRAMES software platform that supports probabilistic analysis

2.4.4. SUM3

The FRAMES software is currently designed for deterministic environmental and human health impact models The Sensitivity/Uncertainty Multimedia Modeling Module (SUM3) software product was designed to allow statistical analysis using the existing deterministic models available in FRAMES within the FRAMES platform SUM3 randomly samples input variables and preserves the associated output values in an external file available to the user for evaluation This enables the user to calculate deterministic values with variable inputs, producing a statistical distribution of results

3. Model Selection Criteria

The following criteria will be used to assess the capabilities of 1) RESRAD 6 0, 2) DandD 2 0, 3) RAC Code and 4) MEPAS/GENII/FRAMES/SUM3 package of computer codes These criteria will be applied to each of the computer codes independently The computer code(s) that meets all or most of the criteria will be chosen for use over those computer models that meet few or none of the criteria This evaluation is not intended to conclude that one model is "better" or "worse" than the others are

These criteria were developed after reviewing the current literature on computer modeling and choosing criteria based on the literature In addition, the computer code must meet the requirements set forth in DOE order 5400 5, Chapter IV In general, the literature supported the use of computer models that comply with project-specific needs and that have been extensively tested

3.1. Criteria #1 - Does the model incorporate key processes from the Conceptual Site Model?

The Site Conceptual Model (SCM) is developed to illustrate how an individual can be exposed to radionuclides in the soil (See Section 4, "Site Conceptual Model, Action Levels for Radionuclides in Soils for the Rocky Flats Cleanup Agreement ", October 31, 1996 and the "Conceptual Model for Actinide Migration Studies at the Rocky Flats Environmental Technology Site", 1998, for a detailed, qualitative description of the relationship between actinide sources and transport pathways) This exposure is then translated by mathematical models into a radiation dose to the individual due to inhalation, ingestion and external irradiation from the radionuclides in the soils The radiation dose caused by a certain soil concentration can then be translated into an RSAL

The SCM must first show the configuration of radionuclides in soil so that the source term can be adequately modeled At RFETS, the source of radionuclides in soils can be in either surface soils or subsurface soils Therefore, the computer model must be able to assess these two soil horizons

The SCM must then be able to trace the contaminant from the source to the exposed individual At RFETS, the environmental transport mechanisms that must be assessed are surface water runoff, surface water stream transport, air resuspension, leaching in the vadose zone and ground water transport Therefore, the computer model must be able to assess all of these environmental transport mechanisms

The SCM must show all the exposure pathways through which an individual could be exposed At RFETS, the exposure pathways of ingestion of soil, inhalation of resuspended soils, external irradiation of soils, ingestion of homegrown fruits/vegetables/grains and ingestion of meat and milk are the exposure pathways of interest at RFETS Therefore, the computer model must be able to assess all of these exposure pathways

The SCM has to include all the exposure scenarios associated with an individual The exposure scenarios of interest at RFETS are the industrial office worker, recreational open space user, wildlife refuge worker, and future resident and future resident rancher The individuals associated with these exposure scenarios may be an adult, child or infant Therefore, the computer model chosen to calculate the RSAL must be able to assess these exposure scenarios

3.2. Criteria #2 - Does the model satisfy study objectives?

The study objective is to estimate the soil concentration that equates to an acceptable radiation dose for all applicable radionuclides over a study period of 1,000 years Therefore, the chosen computer model must be able to trace a radionuclide through the environment to each applicable exposure scenario for a 1,000-year period The maximum radiation dose in this period must be calculated, and the RSAL associated with this maximum concentration must be delineated It would be ideal if the computer code chosen would perform this calculation automatically

3.3. Criteria #3 – Has the model been verified using published analytical equations in scientific and technical journals?

Verification is the process of comparing model outputs with the solutions to analytical equations under the same conditions as the model was run These results need to be equivalent to assure that the analytical equations have been coded into the model correctly The model chosen to calculate the RSAL should be verified

3.4. Criteria #4 – Has the model been validated against known site conditions?

Federal regulations (10CFR 830, 1994) and DOE Order 5700 6C require that the computer code be validated Validation is the process of determining how well the fate and transport model describes actual system behavior Validation of the model can be achieved by matching model output to measurements It involves the process of using a set of input parameter values and boundary conditions for a calibrated model to approximate, within an acceptable range, an independent set of measurements made under conditions similar to the model conditions The model chosen to calculate the RSAL should be validated

Benchmarking may be considered supporting information when assessing the validation of a model Benchmarking is an exercise that consists of solving the same set of problems with several different computer models and comparing results

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3.5. Criteria #5 – Does the model have the capability to satisfy study objectives using probabilistic analysis?

There are two ways to assess radiation dose per the SCM requirements The first method is to choose a single value for each input parameter from the model This is a deterministic analysis Parameters chosen in a deterministic manner will produce a single RSAL for each radionuclide in each exposure scenario The second method is to choose a distribution of values for the most sensitive parameters from the model This is a probabilistic analysis Probabilistic analysis is now regularly applied to environmental modeling Parametric uncertainty deals with the propagation of uncertainty in parameter values through the simulations to the resulting estimates of concentrations in exposure media or to dose The usual tools are Monte Carlo techniques These techniques consist of assigning a probability distribution to each parameter that is treated as uncertain Parameters chosen in a probabilistic manner will produce an output set of radiation dose distributions over time for each radionuclide in each exposure scenario The use of a probabilistic approach was one brought to the attention of the RWG by the Risk Assessment Corporation in their review of the RSALs in 1999 The RWG agreed that this approach allowed more flexibility in the choice of input parameters and made it the fifth criterion The model chosen to calculate the RSAL would have the capability to perform a probabilistic analysis

3.6. Criteria #6 – Is the model well documented?

Federal regulations (10CFR 830, 1994) and DOE Order 5700 6C require that documentation be available that describes the model's equations, and its basis for the calculation Documentation for each model should include 1) A user's manual that discusses how to navigate through the model interface and 2) A technical basis document that outlines the technical aspects (including mathematical formulations) of the radiological source term, the environmental transport algorithms, the exposure pathways factors and the radiation dosimetry algorithms

3.7. Criteria #7 – Is the model available in the public domain?

The model will need to be available in the public domain This means that the model and its' documentation can be accessed either through a government agency or through a private company There may also be a charge associated with the software The model may not be experimental in nature and only available to select individuals

4. Model Criteria Evaluation

The Model Selection criteria will now be applied to 1) RESRAD 6 0, 2) DandD 2 0, 3) RAC Code and 4) MEPAS/GENII/FRAMES/SUM3 package of computer codes independently The results of applying these criteria to each computer model will be used to select the appropriate computer code to calculate the RSAL The results of applying these model selection criteria are outlined in Table 1, "Model Selection Criteria Assessment," of Section 5 0

4.1. RESRAD 6.0

4.1.1. Criteria #1 - Does the model incorporate key processes from the Site Conceptual Model?

RESRAD 6 0 can assess all aspects of the SCM applicable at RFETS RESRAD 6 0 can trace a contaminant from its origin in soils to an exposed individual through all applicable exposure pathways RESRAD 6 0 can assess radionuclides in surface soils and subsurface soils RESRAD 6 0 can assess the exposure pathways of ingestion of soil, inhalation of resuspended soils, external irradiation of soils, ingestion of homegrown fruits/vegetables/grains and ingestion of meat and milk RESRAD 6 0 can assess the industrial office worker, recreational open space user, wildlife refuge worker, and hypothetical future resident and hypothetical future resident rancher exposure scenarios RESRAD 6 0 can assess an adult, child and infant within the appropriate exposure scenarios

4.1.2. Criteria #2 - Does the model satisfy study objectives?

RESRAD 6 0 can estimate the soil concentration that equates to an acceptable radiation dose for all applicable radionuclides over a study period of 1,000 years RESRAD 6 0 can trace a radionuclide through the environment to each applicable exposure scenario for a 1,000-year period The maximum radiation dose in this period can be calculated by RESRAD 6 0, and the RSAL associated with this maximum concentration can be delineated by RESRAD 6 0 RESRAD 6 0 can perform this calculation automatically

4.1.3. Criteria #3 – Has the model been verified using published analytical equations in scientific and technical journals?

The series of RESRAD computer code has been extensively verified Verification of RESRAD has included the following

1 Argonne National Laboratory performed an internal verification of the RESRAD computer code using hand calculations before its initial release in 1989
2 An independent verification of RESRAD was performed in 1994 and is documented in "Verification of RESRAD, A Code for Implementing Residual Radioactive Material Guidelines, Version 5 03," HNUS-ARPD-94-174, Halliburton NUS Corporation, June 1994

3 Argonne National Laboratory is in the process of contracting for an independent Verification of RESRAD 6 0 that should be concluded in early winter 2001

4.1.4. Criteria #4 – Has the model been validated against known site conditions?

The RESRAD computer code has been validated Validation of RESRAD is documented in the following reports

1 Analysis of BIOMOVS II Uranium Mill Tailings Scenario 1 07 with the RESRAD Computer Code, ANL/EAD/TM-66, Argonne National Laboratory, August 1997
2 Application of the RESRAD Computer Code to VAMP Scenario S, ANL/EAD/TM-70, Argonne National Laboratory, March 1997

BIOMOVS (BIOspheric MOdel Validation Study) II is an international cooperative study to test models designed to quantify the environmental transfer and bioaccumulation of radionuclides and other trace substances Scenario 1 07 of the BIOMOVS study is the culmination of numerous iterations among the members of this working group in developing a hypothetical scenario, comparing predictions of the intermediate scenarios, and refining and clarifying the scenario to arrive at a reasonably well-defined scenario to serve as the basis for comparison of deterministic predictions of the models participating in the study

VAMP (Validation of Environmental Model Predictions) is an international program established by the International Atomic Energy Agency (IAEA) in 1988 to use data from the Chernobyl fallout to test and improve biospheric models Scenario S involved the prediction of the radiological consequences of cesium-137 from Chernobyl-driven fallout in southern Finland

RESRAD has been extensively benchmarked

4.1.5. Criteria #5 – Does the model have the capability to satisfy study objectives using probabilistic analysis?

RESRAD 6 0 can assess radiation dose per the SCM requirements using deterministic and/or probabilistic analysis RESRAD 6 0 has the capability to choose a single conservative value for each input parameter for the model to support a deterministic analysis RESRAD 6 0 also has the capability to choose a distribution of values for the most sensitive parameters for the model to support a probabilistic analysis RESRAD 6 0 can perform sensitivity analyses so that the most sensitive parameters can be delineated RESRAD 6 0 has the capability to produce an output set of radiation dose distributions over time for each radionuclide in each exposure scenario

4.1.6. Criteria #6 – Is the model well documented?

RESRAD 6 0 is very well documented The following reports have been published to support the use of RESRAD 6 0

1 Probabilistic Modules for RESRAD and RESRAD-BUILD Computer Code, ANL/EAD/TM-91, Argonne National Laboratory, June 2000
2 Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5 0, Working Draft For Comment, ANL/EAD/LD-2, Argonne National Laboratory, September 1993
3 Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil, ANL/EAIS-8, Argonne National Laboratory, April 1993
4 Evaluation of the Area Factor Used in the RESRAD Code for the Estimation of Airborne Contaminant Concentrations of Finite Area Sources, ANL/EAD/TM-82, Argonne National Laboratory, July 1998
5 External Exposure Model Used in the RESRAD Code for Various Geometries of Contaminated Soil, ANL/EAD/TM-84, Argonne National Laboratory, September 1998

4.1.7. Criteria #7 – Is the model available in the public domain?

RESRAD 6 0 is available in the public domain RESRAD 6 0 and documentation can be accessed through the Nuclear Regulatory Commission website at http //www nrc gov/RES/rescodes htm There is no charge associated with this software The computer codes themselves can only be obtained with special permission from Argonne National Laboratory

4.2. DandD 2.0

4.2.1. Criteria #1 - Does the model incorporate key processes from the Site Conceptual Model?

DandD 2 0 is a screening level computer code and therefore cannot assess all aspects of the SCM applicable at RFETS DandD 2 0 can trace a contaminant from its origin in soils to an exposed individual through all applicable exposure pathways DandD 2 0 can assess radionuclides in surface soils only and not subsurface soils DandD 2 0 can assess the exposure pathways of ingestion of soil, inhalation of resuspended soils, external irradiation of soils, ingestion of homegrown fruits/vegetables/grains and ingestion of meat and milk DandD 2 0 cannot assess the industrial office worker, recreational open space user, wildlife refuge worker, and hypothetical future resident and hypothetical future resident rancher exposure scenarios DandD 2 0 cannot assess an adult, child and infant within the appropriate exposure scenarios DandD only assesses an adult in a residential setting

4.2.2. Criteria #2 - Does the model satisfy study objectives?

DandD 2 0 can estimate the soil concentration that equates to an acceptable radiation dose for all applicable radionuclides over a study period of 1,000 years DandD 2 0 can trace a radionuclide through the environment to each applicable exposure scenario for a 1,000-year period DandD 2 0 can calculate the maximum radiation dose in this period, and DandD 2 0 can delineate the RSAL associated with this maximum concentration DandD 2 0 can perform this calculation automatically

4.2.3. Criteria #3 – Has the model been verified using published analytical equations in scientific and technical journals?

DandD 2 0 has not been verified in a manner that can be documented

4.2.4. Criteria #4 – Has the model been validated against known site conditions?

DandD 2 0 has not been validated or benchmarked However, during the RSAL Working Group meetings in the past years DanD was compared to earlier versions of RESRAD, but no report validating its use was published

4.2.5. Criteria #5 – Does the model have the capability to satisfy study objectives using probabilistic analysis?

DandD 2 0 cannot assess radiation dose per the SCM requirements per Criteria #1, but DandD 2 0 has the capability to incorporate deterministic and/or probabilistic analyses DandD 2 0 though is meant to be a screening level computer model that has no inputs changed and gives a conservative cleanup level as output DandD 2 0 has the capability to choose a single conservative value for each input parameter for the model to support a deterministic analysis DandD 2 0 also has the capability to choose a distribution of values for the most sensitive parameters for the model to support a probabilistic analysis The sensitivity analysis has already been performed for DandD 2 0, and distributions of values have been incorporated into the model for the most sensitive parameters DandD 2 0 has the capability to produce an output set of radiation dose distributions over time for each radionuclide in each exposure scenario

4.2.6. Criteria #6 – Is the model well documented?

DandD 2 0 is very well documented The following reports have been published to support the use of DandD 2 0

1 Residual Radioactive Contamination From Decommissioning Technical Basis for Translating Contamination Levels to Annual Effective Dose

Equivalent, Final, Volume 1, NUREG/CR-5512, US Nuclear Regulatory Commission, October 1992
2 Residual Radioactive Contamination From Decommissioning User's Manual, Draft, Volume 2, NUREG/CR-5512, US Nuclear Regulatory Commission, May 1999
3 Residual Radioactive Contamination From Decommissioning Parameter Analysis, Draft, Volume 3, NUREG/CR-5512, US Nuclear Regulatory Commission, April 1996

4.2.7. Criteria #7 – Is the model available in the public domain?

DandD 2 0 is available in the public domain. DandD 2 0 and its' documentation can be accessed through the Nuclear Regulatory Commission website at http //www nrc gov/RES/rescodes htm There is no charge associated with this software

4.3. RAC Code

4.3.1. Criteria #1 - Does the model incorporate key processes from the Site Conceptual Model?

RAC Code can assess all aspects of the SCM applicable at RFETS RAC Code can trace a contaminant from its origin in soils to an exposed individual through all applicable exposure pathways RAC Code can assess radionuclides in surface soils and subsurface soils RAC Code can assess the exposure pathways of ingestion of soil, inhalation of resuspended soils, external irradiation of soils, ingestion of homegrown fruits/vegetables/grains and ingestion of meat and milk RAC Code can assess the industrial office worker, recreational open space user, wildlife refuge worker, and hypothetical future resident and hypothetical future resident rancher exposure scenarios RAC Code can assess an adult, child and infant within the appropriate exposure scenarios

4.3.2. Criteria #2 - Does the model satisfy study objectives?

RAC Code can estimate the soil concentration that equates to an acceptable radiation dose for all applicable radionuclides over a study period of 1,000 years RAC Code can trace a radionuclide through the environment to each applicable exposure scenario for a 1,000-year period The RAC Code can calculate the maximum radiation dose in this period

4.3 3. Criteria #3 – Has the model been verified using published analytical equations in scientific and technical journals?

RAC Code has not been verified as a set of computer codes The RESRAD baseline portion of RAC Code that has not been modified has been verified, but the RAC generated computer code has not been verified The documentation listed in Criteria #3 for RESRAD 6 0 are applicable to this version of RESRAD The RAC generated portion of RAC Code has not been verified in a manner that can be documented

4.3.4. Criteria #4 – Has the model been validated against known site conditions?

RAC Code has not been validated as a set of computer codes The RESRAD baseline portion of RAC Code that has not been modified has been validated, but the RAC generated computer code has not been validated The documentation listed in Criteria #4 for RESRAD 6 0 are applicable to this version of RESRAD The RAC generated portion of RAC Code has not been validated

RAC Code has not been benchmarked as a set of computer codes The RESRAD portion of RAC Code that has not been modified has been benchmarked though (See RESRAD 6 0, Criteria #4)

4.3.5. Criteria #5 – Does the model have the capability to satisfy study objectives using probabilistic analysis?

RAC Code can assess radiation dose per the SCM requirements using deterministic and/or probabilistic analysis RAC Code has the capability to choose a single conservative value for each input parameter for the model to support a deterministic analysis RAC Code also has the capability to choose a distribution of values for the most sensitive parameters for the model to support a probabilistic analysis RAC Code can perform sensitivity analyses so that the most sensitive parameters can be delineated by using RESRAD 5 82 only RAC Code, as presented, does not appear to have the capability to produce an output set of radiation dose distributions over time for each radionuclide in each exposure scenario

4.3.6. Criteria #6 – Is the model well documented?

RAC Code is not a well-documented set of computer codes The RESRAD baseline portion of RAC Code that has not been modified is very well documented, but the RAC generated computer code is not well documented The documentation listed in parts 2 through 5 of Criteria #6 for RESRAD 6 0 are applicable to this version of RESRAD RAC Code is only documented through a 1 5 page README file that comes with the code RAC Code is also documented through comments within the raw computer coding This README file with the raw computer code comments is insufficient to run the RAC Code computer model

4.3.7. Criteria #7 – Is the model available in the public domain?

RAC Code is available in the public domain RAC Code and its' documentation can be obtained through the Rocky Flats Citizens Advisory Board There is no charge associated with this software

4.4. MEPAS/GENII/FRAMES/SUM3

4.4.1. Criteria #1 - Does the model incorporate key processes from the Site Conceptual Model?

MEPAS/GENII/FRAMES/SUM3 can assess all aspects of the CSM applicable at RFETS MEPAS/GENII/FRAMES/SUM3 can trace a contaminant from its origin in soils to an exposed individual through all applicable exposure pathways MEPAS/GENII/FRAMES/SUM3 can assess radionuclides in surface soils and subsurface soils MEPAS/GENII/FRAMES/SUM3 can assess the exposure pathways of ingestion of soil, inhalation of resuspended soils, external irradiation of soils, ingestion of homegrown fruits/vegetables/grains and ingestion of meat and milk MEPAS/GENII/FRAMES/SUM3 can assess the industrial office worker, recreational open space user, wildlife refuge worker, and hypothetical future resident and hypothetical future resident rancher exposure scenarios MEPAS/GENII/FRAMES/SUM3 can assess an adult, child and infant within the appropriate exposure scenarios

4.4.2. Criteria #2 - Does the model satisfy study objectives?

MEPAS/GENII/FRAMES/SUM3 can estimate the soil concentration that equates to an acceptable radiation dose for all applicable radionuclides over a study period of 1,000 years MEPAS/GENII/FRAMES/SUM3 can trace a radionuclide through the environment to each applicable exposure scenario for a 1,000-year period The maximum radiation dose in this period can be calculated by MEPAS/GENII/FRAMES/SUM3, and the RSAL associated with this maximum concentration can be delineated by MEPAS/GENII/FRAMES/SUM3

4.4.3. Criteria #3 – Has the model been verified using published analytical equations in scientific and technical journals?

The MEPAS/GENII/FRAMES/SUM3 computer code has been extensively verified Verification of MEPAS/GENII/FRAMES/SUM3 has included the following

1 Test Plan and Baseline Testing Results for the MEPAS 4 1 - Computed Source Term Release Module, Pacific Northwest National Laboratory, R Taira, December 1999

2 Test Plan and Baselme Testmg Results for the MEPAS 4 1 - Vadose Zone Transport Module, Pacific Northwest National Laboratory, J McDonald, December 1999
3 Test Plan and Baselme Testmg Results for the MEPAS 4 1 - Saturated Zone (Aquifer) Transport Module, Pacific Northwest National Laboratory, J McDonald, December 1999
4 Test Plan and Baselme Testmg Results for the MEPAS 4 1 - Surface Water (Non-Tidal River) Transport Module, Pacific Northwest National Laboratory, J McDonald, December 1999
5 Test Plan and Baselme Testmg Results for the MEPAS 4 1 - Atmospheric Transport Module, Pacific Northwest National Laboratory, J McDonald & C Fosmire, December 1999
6 Test Plan and Baselme Testmg Results for the MEPAS 4 1 - Chronic Exposure Module, Pacific Northwest National Laboratory, R Taira & S Snyder, December 1999
7 Test Plan and Baselme Testmg Results for the MEPAS 4 1 - Intake Module, Pacific Northwest National Laboratory, R Taira, December 1999
8 Test Plan and Baselme Testmg Results for the MEPAS 4 1 - Human Health Impact Module, Pacific Northwest National Laboratory, R Taira, December 1999
9 GENII "Conversion Testing, Verification, and Validation of Software" plan listing 42 tests performed as of 2/7/1989, Napier, 1990
10 Hand calculations performed to support acute models in GENII, Sawyer, L H , T A. Ikenberry, 1991
11 Hand Calculations performed on GENII to support NPR-EIS program, Nelson, I C , L H Sawyer, T A Ikenberry 1990
12 GENII Hand Calculation Worksheets, version of February 2, 1994, Peloquin, R A., 1994
13 Test Plan and Baselme Testmg Results for the FRAMES User Interface, Pacific Northwest National Laboratory, R Tiara, December 1999
14 Test Plan and Baselme Testmg Results for the FRAMES Viewers, Pacific Northwest National Laboratory, R Lundgren, December 1999
15 Test Plan and Baselme Testmg Results for the FRAMES User Defined Source Module, Pacific Northwest National Laboratory, M Eslinger, August 1999
16 Test Plan and Baselme Testmg Results for the FRAMES User Defined Water Transport Module, Pacific Northwest National Laboratory, M Eslinger, August 2000
17 Test Plan and Baselme Testmg Results for the FRAMES User Defined Air Transport Module, Pacific Northwest National Laboratory, M Eslinger, August 2000
18 Test Plan and Baselme Testmg Results for the FRAMES User Defined Exposure Pathway Module, Pacific Northwest National Laboratory, M Eslinger, August 2000
19 Test Plan and Baselme Testmg Results for the Sensitivity/ Uncertainty Multimedia Modeling Module (SUM3) Pacific Northwest National Laboratory, R Taira, September 2000

20 An Approach to Ensurıng Qualıty In Envıronmental Software, PNNL-11880, Pacıfic Northwest Natıonal Laboratory, G M Gelston, R E Lundgren, J P McDonald, B L Hoopes, May 1998

4.4.4. Criteria #4 – Has the model been validated against known site conditions?

The MEPAS & GENII computer codes have been extensıvely valıdated Valıdatıons of MEPAS & GENII are documented ın the followıng reports

1 A Demonstratıon of the Applıcabılıty of Implementıng the Enhanced Remedıal Actıon Prıorıty System (RAPS) for Envıronmental Releases, PNL-7102, Pacıfic Northwest Natıonal Laboratory, G Whelan, J G Droppo, D L Strenge, M B Walter, J W Buck, December 1989
2 Summary Technıcal Revıew of the Multımedıa Envıronmental Pollutant Assessment System (MEPAS), Prepared for the Office of Federal Facılıtıes Enforcement, US EPA, ICF Incorporated, November 1991
3 Valıdatıon of Models usıng Chernobyl Fallout Data from the Central Bohemıa Regıon of the Czech Republıc Scenarıo CB (GENII Valıdatıon), IAEA-TECDOC-795, Fırst Report of the VAMP Multıple Pathways Assessment Workıng Group, Internatıonal Atomıc Energy Agency, 1995
4 A Comparıson of Envıronmental Radıonuclıde Concentratıons Calculated by a Mathematıcal Model wıth Measured Concentratıons (GENII Valıdatıon), PNL-SA-14720, In Proceedıngs of ANS Topıcal Conference on Populatıon Exposure from the Nuclear Fuel Cycle Oak Rıdge, Tennessee Jaquısh, R E , and B A Napıer 1987

MEPAS & GENII have been extensıvely benchmarked

4.4.5. Criteria #5 – Does the model have the capability to satisfy study objectives using probabilistic analysis?

MEPAS/GENII/FRAMES/SUM3 can assess radıatıon dose per the CSM requırements usıng determınıstıc and/or probabılıstıc analysıs MEPAS/GENII/FRAMES/SUM3 has the capabılıty to choose a sıngle conservatıve value for each ınput parameter for the model to support a determınıstıc analysıs MEPAS/GENII/FRAMES/SUM3 also has the capabılıty to choose a dıstrıbutıon of values for the most sensıtıve parameters for the model to support a probabılıstıc analysıs MEPAS/GENII/FRAMES/SUM3 can perform sensıtıvıty analyses so that the most sensıtıve parameters can be delıneated MEPAS/GENII/FRAMES/SUM3 does have the capabılıty to produce an output set of radıatıon dose dıstrıbutıons over tıme for each radıonuclıde ın each exposure scenarıo

4.4.6. Criteria #6 – Is the model well documented?

MEPAS/GENII/FRAMES/SUM3 is very well documented The following reports have been published to support the use of MEPAS/GENII/FRAMES/SUM3

1 Multimedia Environmental Pollutant Assessment System (MEPAS) Guidance, Guidelines for Evaluating MEPAS Input Parameters for Version 3 1, Pacific Northwest Laboratory, June 1997
2 Multimedia Environmental Pollutant Assessment System (MEPAS) Formulations, Compilation of Mathematical Formulations for MEPAS Version 3 2, Pacific Northwest National Laboratory, February 1997
3 GENII Version 2 User's Guide, Pacific Northwest National Laboratory, January 1999
4 GENII Version 2 Software Design Document, Pacific Northwest National Laboratory, January 1999
5 Concepts of a Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES), Pacific Northwest National Laboratory, October 1997
6 GENII Version 2 Sensitivity/Uncertainty Multimedia Modeling Module User's Guidance, Draft, Pacific Northwest National Laboratory, December 1998
7 Sensitivity/Uncertainty Multimedia Modeling Module (SUM3) User's Guide, Pacific Northwest National Laboratory, http //mepas pnl gov 2080/earth/sum3/sum3ug/sum3ug htm

4.4.7. Criteria #7 – Is the model available in the public domain?

MEPAS/GENII/FRAMES/SUM3 is available in the public domain MEPAS/GENII/FRAMES/SUM3 and documentation can be accessed through the Pacific Northwest National Laboratory website at http //mepas.pnl gov. 2080/earth/earth htm There is no charge associated with this software for Department of Energy contractors There is a charge for these computer models and documentation to the general public

5. Conclusions

RESRAD 6 0 and MEPAS/GENII/FRAMES/SUM3 are the computer codes that satisfy all of the selection criteria Therefore RESRAD 6 0 and MEPAS/GENII/FRAMES/SUM3 may be used to calculate RSALs at RFETS Both of these computer models would produce accurate results for Rocky Flats parameters if selected Results from using RESRAD 6 0 would be directly comparable to the results of past calculations of RSALs at the Site Since RESRAD has previously been used at RFETS to derive RSALs and the Public reviewing the RSALs is familiar with RESRAD, RESRAD 6 0 should be used to calculate RSALs at RFETS

Table 1, "Model Selection Criteria Assessment," outlines each of the four computer models with the model selection criteria

Also, as noted in the introduction, the RFCA parties have agreed to calculate a matrix of potential RSALs using various scenarios, which fit in the risk range of 10^{-4}, 10^{-5} and 10^{-6} The risk levels will be calculated using the standard slope factor method that has been employed by EPA for over 10 years The method for performing this type of calculation is provided in EPA's "Risk Assessment Guidance for Superfund (RAGS)" Volume I (1989) The Task 3 report describes the RAGS process, results and lists all equations and parameters used for the spreadsheet calculations

TABLE 1
MODEL SELECTION CRITERIA ASSESSMENT

Computer Model vs Selection Criteria	RESRAD 6.0	DandD 2.0	RAC Code	FRAMES MEPAS GENII SUM3
Criteria #1	YES	NO	YES	YES
Criteria #2	YES	YES	NO	YES
Criteria #3	YES	NO	NO	YES
Criteria #4	YES	NO	NO	YES
Criteria #5	YES	NO	NO	YES
Criteria #6	YES	YES	NO	YES
Criteria #7	YES	YES	YES	YES

6. References

ASTM, Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites, E1739-95e1, November, 1995

ASTM Technical & Professional Training, RBCA Fate and Transport Models Compendium and Selection Guidance, 1999

DOE, Rocky Flats Environmental Technology Site, Human Health Risk Assessment Model Description, Operable Unit 3, Technical Memorandum No 3, March 6, 1995

DOE, Rocky Flats Environmental Technology Site, Draft Description of Models for the Human Health Risk Assessment, Operable Unit 4, Technical Memorandum No 5, March 1993

DOE, Rocky Flats Environmental Technology Site, Final Human Health Risk Assessment Model Description, Operable Unit 5, Technical Memorandum No 13, November 17, 1994

EPA Fact Sheet Documenting Ground Water Modeling at Sites Contaminated with Radioactive Substances, EPA 540-F-96/002, January 1996

EPA Fact Sheet Computer Models Used to Support Cleanup Decision making at Hazardous and Radioactive Waste Sites, EPA/540/F-94-022, January, 1996

EPA Fact Sheet Environmental Characteristics of EPA, NRC, and DOE Sites Contaminated with Radioactive Substances, EPA 540-F-94-023, January 1996

EPA Fact Sheet Environmental Pathway Models – Ground-Water Modeling in Support of Remedial Decision Making at Sites Contaminated With Radioactive Material, EPA/540/F-94-024, January, 1996

EPA Fact Sheet A Technical Guide to Ground-Water Model Selection at Sites Contaminated with Radioactive Substances, EPA/540/F-94-025, and January 1996

Risk Assessment Corporation, Task 2 Computer Models, Final Report, July 1999

RESRAD AIR CALCULATIONS, Prepared for KH by Radian International, February 2001